(12) UK Patent Application (19) GB (11) 2 329 291 (13) A

(43) Date of A Publication 17.03.1999

(21) Application No 9819930.0

(22) Date of Filing 14.09.1998

(30) Priority Data
(31) 97047032 (32) 12.09.1997 (33) KR

(71) Applicant(s)
Samsung Electronics Co Limited
(Incorporated in the Republic of Korea)
416 Maetan-dong, Paldal-gu, Suwon-city,
Kyungki-do, Republic of Korea

(72) Inventor(s)
Jin-Han Kim
Won-Ha Choe
Soong-Hee Lee

(74) Agent and/or Address for Service
Dibb Lupton Alsop
Fountain Precinct, Balm Green, SHEFFIELD, S1 1RZ,
United Kingdom

(51) INT CL⁶
H04J 14/02

(52) UK CL (Edition Q)
H4B BKX

(56) Documents Cited
GB 2315178 A EP 0639177 A1 WO 94/06226 A1
US 5452115 A

(58) Field of Search
UK CL (Edition P) H4B BKX
INT CL⁶ H04J 14/02
ONLINE: WPI, EPODOC, JAPIO

(54) Abstract Title
Wavelength allocation in an optical fibre subscriber network

(57) A wavelength division multiplexed (WDM) optical fibre subscriber network capable of expanding the number of the subscribers. A central office allocates a combination of common optical wavelengths to a subscriber upon receipt of a service request signal. These allocated wavelengths form a sub-set of all the common wavelengths in the network. Information destined for different subscribers is transmitted on each common wavelength. The central office also allocates to each subscriber appropriate bandwidth on the allocated wavelengths. Optical subscriber devices each optically distribute and filter the multiplexed optical signals to select their allocated optical wavelengths, and output the selected optical wavelengths to corresponding subscriber terminals. The sub-set of wavelengths allocated to each subscriber may be unique to that subscriber. The network may use A.T.M. or packet switching protocols.

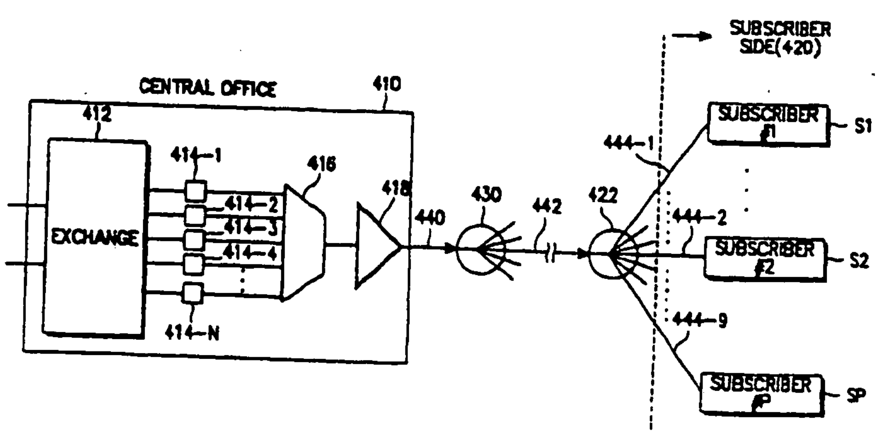

FIG. 4

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

GB 2 329 291 A

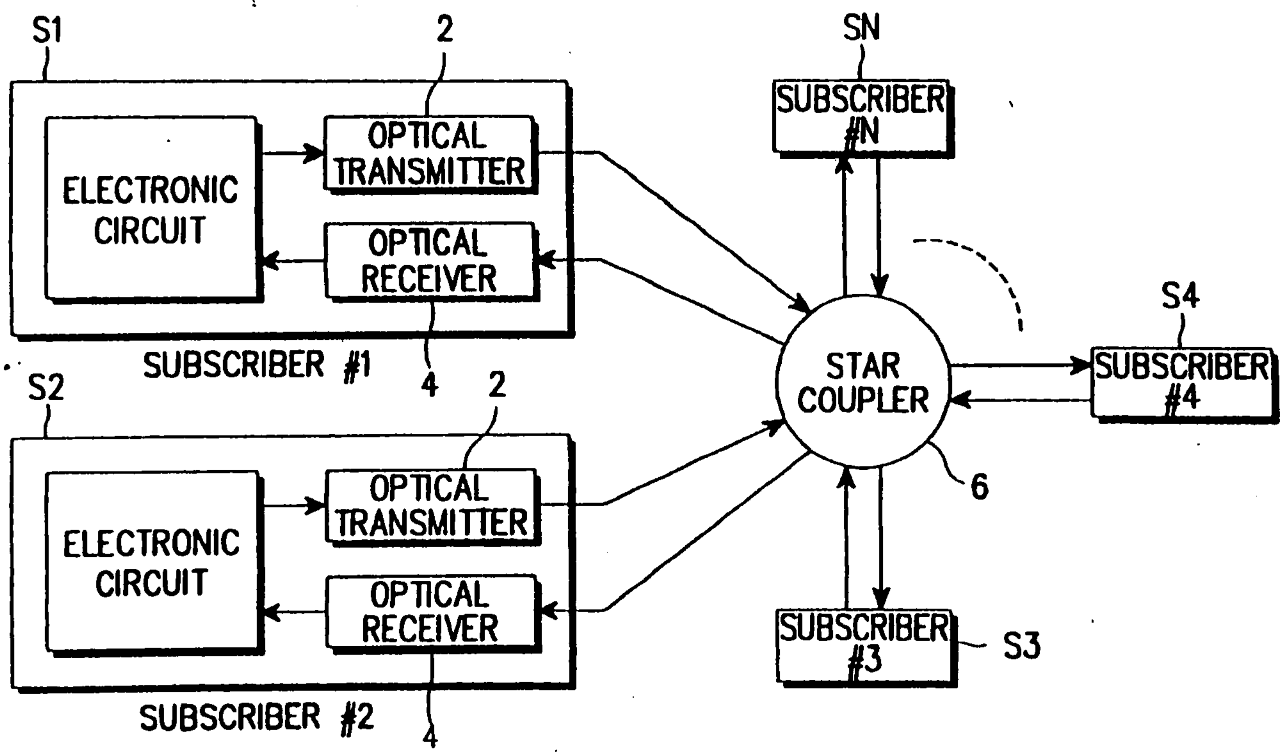
S1
2
ELECTRONIC CIRCUIT
OPTICAL TRANSMITTER
OPTICAL RECEIVER
SUBSCRIBER #1
4
S2
2
ELECTRONIC CIRCUIT
OPTICAL TRANSMITTER
OPTICAL RECEIVER
SUBSCRIBER #2
4
SN
SUBSCRIBER #N
STAR COUPLER
6
S4
SUBSCRIBER #4
SUBSCRIBER #3
S3

FIG. 1

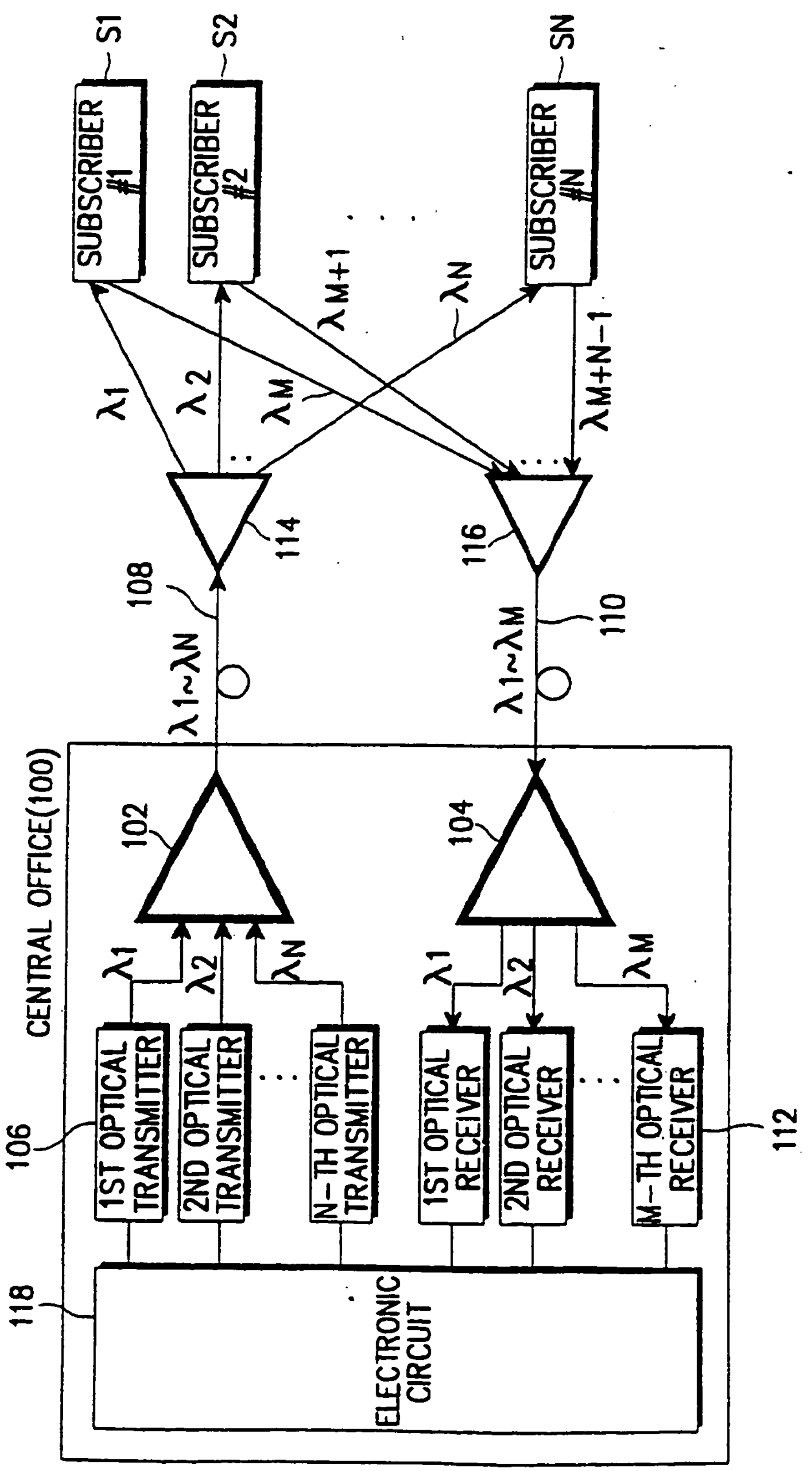
SUBSCRIBER #1
S1
SUBSCRIBER #2
S2
SUBSCRIBER #N
SN
λ1
λ2
λM
λN
λM+1
λM+N−1
114
116
108
110
λ1~λN
λ1~λM
CENTRAL OFFICE(100)
102
104
λ1
λ2
λN
λ1
λ2
λM
1ST OPTICAL TRANSMITTER
2ND OPTICAL TRANSMITTER
N−TH OPTICAL TRANSMITTER
1ST OPTICAL RECEIVER
2ND OPTICAL RECEIVER
M−TH OPTICAL RECEIVER
106
112
118
ELECTRONIC CIRCUIT

FIG. 2

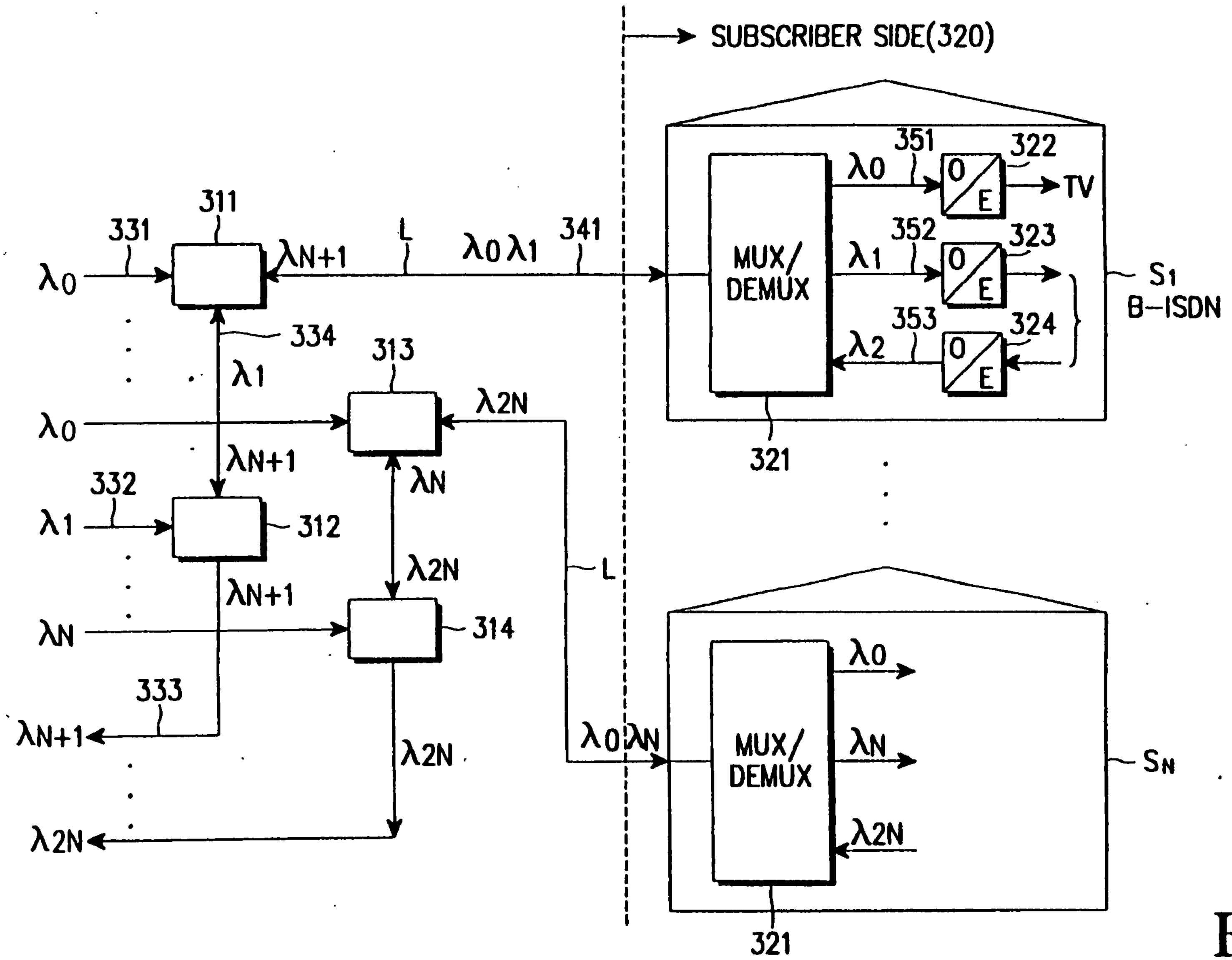
SUBSCRIBER SIDE(320)
λ0
λ0
λ1
λN
λN+1
λ2N
331
332
333
334
311
312
313
314
L
λ0 λ1
341
λN+1
λ1
λN
λ2N
L
λ0 λN
MUX/ DEMUX
321
λ0
λ1
λ2
351
352
353
322
323
324
TV
S1
B-ISDN
SN

FIG. 3

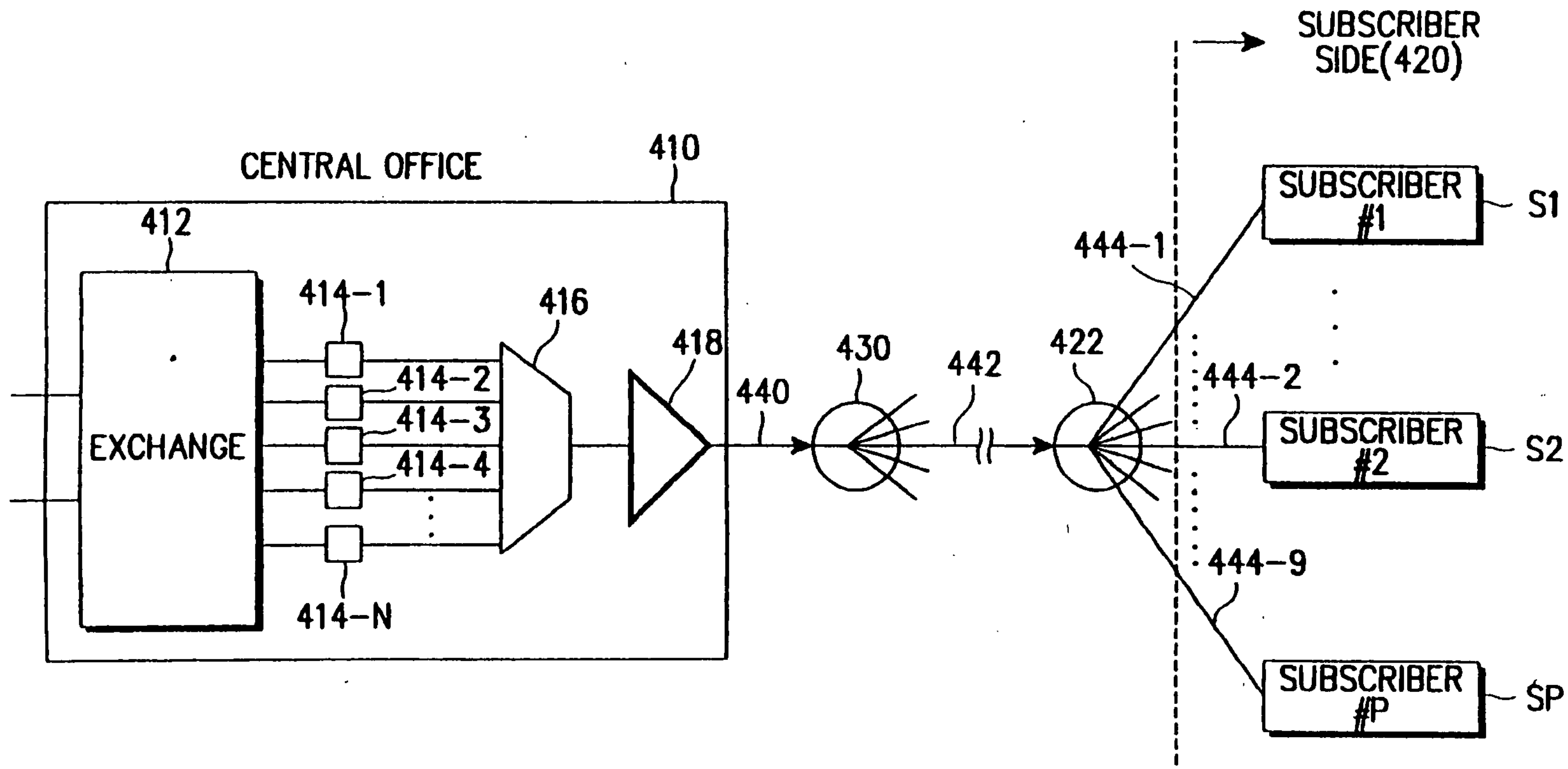
CENTRAL OFFICE
410
412
EXCHANGE
414-1
414-2
414-3
414-4
414-N
416
418
440
430
442
422
444-1
444-2
444-9
SUBSCRIBER SIDE(420)
SUBSCRIBER #1
SUBSCRIBER #2
SUBSCRIBER #P
S1
S2
SP

FIG. 4

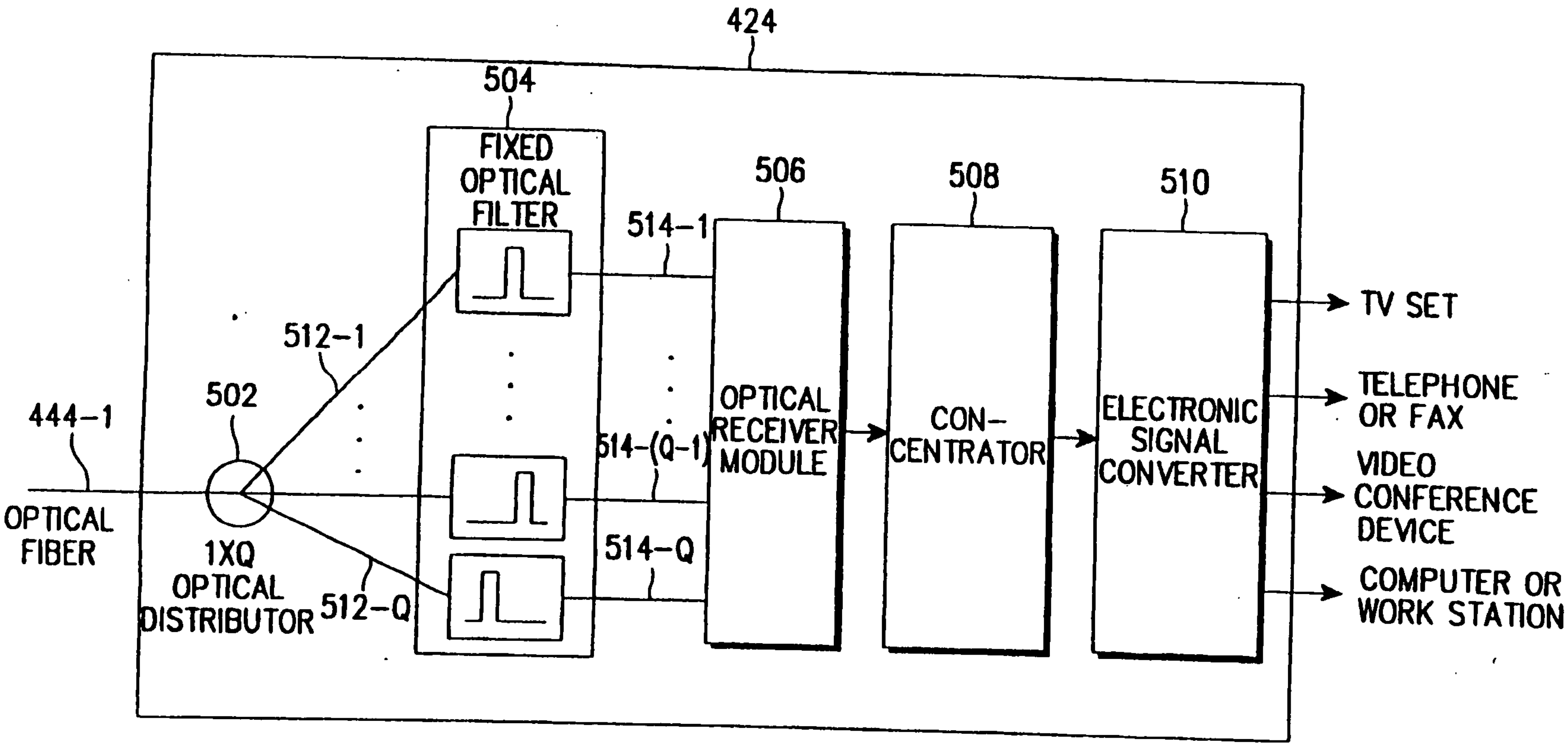
424
504
FIXED
OPTICAL
FILTER
506
508
510
514-1
514-(Q-1)
514-Q
444-1
502
512-1
512-Q
OPTICAL
FIBER
1XQ
OPTICAL
DISTRIBUTOR
OPTICAL
RECEIVER
MODULE
CON-
CENTRATOR
ELECTRONIC
SIGNAL
CONVERTER
TV SET
TELEPHONE
OR FAX
VIDEO
CONFERENCE
DEVICE
COMPUTER OR
WORK STATION

FIG. 5

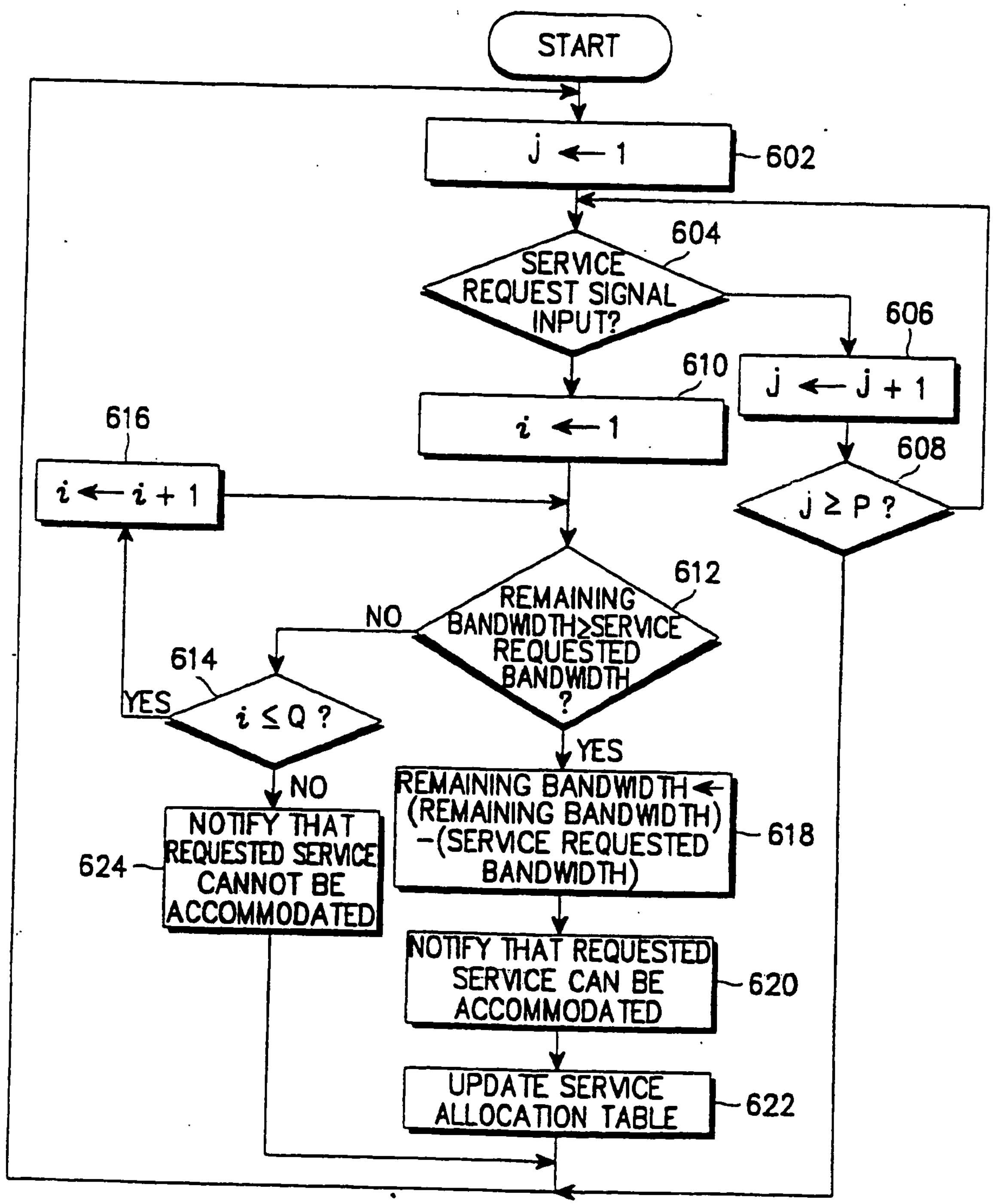
START
j ← 1
602
604
SERVICE REQUEST SIGNAL INPUT?
606
j ← j + 1
608
j ≥ P ?
610
i ← 1
616
i ← i + 1
612
REMAINING BANDWIDTH≥SERVICE REQUESTED BANDWIDTH ?
NO
614
YES
i ≤ Q ?
NO
YES
REMAINING BANDWIDTH← (REMAINING BANDWIDTH) −(SERVICE REQUESTED BANDWIDTH)
618
624
NOTIFY THAT REQUESTED SERVICE CANNOT BE ACCOMMODATED
NOTIFY THAT REQUESTED SERVICE CAN BE ACCOMMODATED
620
UPDATE SERVICE ALLOCATION TABLE
622

FIG. 6

2329291

OPTICAL FIBRE SUBSCRIBER NETWORK

The present invention relates to an optical fibre subscriber network, and in particular, to a WDM (wavelength division multiplexing) optical fibre subscriber network with an increased number of the subscribers.

Background to the Invention

As high speed data communication and video communication services progress along with the development of an information-oriented society, there have been demands for a wideband communication network capable of providing communication services mentioned above as well as the conventional voice communication service. To realise a wideband communication network, it is important to build an optical fibre subscriber network.

A WDM (wavelength division multiplexing) optical fibre subscriber network is widely used because the transmission capacity is increased without increasing the transmission speed of each wavelength. Reference will be made to the conventional WDM optical fibre subscriber networks, as shown in FIGs. 1 to 3.

Referring to FIG. 1, a first conventional WDM optical fibre subscriber network includes N subscriber devices S1-SN each having an optical transmitter 2 and an optical receiver 4, and a star coupler 6 for star-coupling the subscriber devices S1-SN. In operation, the optical transmitters 2 in the respective subscriber devices S1-SN each output optical signals of a corresponding wavelength

λ_1-λ_N through optical transmission lines (i.e. optical fibres) connected to the star coupler 6. The star coupler 6 then couples the received optical signals and distributes the coupled signals to the optical transmission lines connected the optical receivers 4 in the respective subscriber devices S1-SN. Here, the optical receivers 4 each have a wavelength selection filter for selectively passing the optical signal of a specific wavelength, unique to that subscriber.

Referring to FIG. 2, a second conventional PPL-type (Passive Photonic Loop type) WDM optical fibre subscriber network combines and distributes N wavelengths by using WDM multiplexers 102 and 116 and WDM demultiplexers 104 and 114 and then connects the wavelengths to the respective subscriber devices S1-SN.

As to the configuration, a central office 100 consists of N optical transmitters 106 for transmitting optical signals of the wavelengths λ_1-λ_N, a WDM multiplexer 102 for multiplexing (combining) the optical signals output from the optical transmitters 106 and transmitting the multiplexed optical signals via an optical transmission line (i.e. optical fibre) 108. The central office 100 further comprises a WDM demultiplexer 104 for demultiplexing the optical signals of wavelengths λ_1-λ_M transmitted upward from the subscriber side through an optical transmission line 110, and M optical receivers 112 for receiving th optical signals distributed (demultiplexed) by the WDM demultiplexer 104.

The subscriber side, consisting of a WDM demultiplexer 114 and a WDM multiplexer 116 which are shared by N subscribers, is connected to the central office 100 via the optical transmission lines 108 and 110. The WDM demultiplexer 114 in the subscriber side distributes each of the optical signals of wavelengths λ_1-λ_N received through the optical transmission line 108 to the respective subscriber device S1-SN. The WDM multiplexer 116 combines (multiplexes) optical signals of wavelengths λ_1-λ_N transmitted upward from the subscriber devices S1-SN and transmits the combined signals to the central 100 via the optical transmission line 110.

In downward transmission of the optical signals (from the central office 100 to the subscriber side), the optical transmitters 106 of the central office 100 convert the electric signals output from the electronic circuit 118 to optical signals of corresponding wavelengths λ_1-λ_N, and the WDM multiplexer 102 combines the optical signals output from the optical transmitters 106 and transmits the combined optical signals to the WDM demultiplexer 114 through the downward optical transmission line 108. The WDM demultiplexer 114 then distributes the received optical signals of the wavelengths λ_1-λ_N to the respective subscriber devices S1-SN.

In upward transmission of the optical signals (from the subscriber side to the central office 100), the subscriber devices S1-SN transmit optical signals of the wavelengths λ_1-λ_N, and the WDM multiplexer 116 combines the optical signals output from the subscriber devices

S1-SN and transmits the combined optical signals to the WDM demultiplexer 104 through the upward optical transmission line 110. The WDM demultiplexer 104 then distributes the optical signals of wavelengths λ_1-λ_N to the corresponding optical receivers 112, which convert the received optical signals to electric signals and output the converted electric signals to the electronic circuit 118.

Referring to FIG. 3, a third conventional WDM optical fibre subscriber network uses different wavelengths according to the types of the distributive services. Further, respective subscribers use different wavelengths for the upward/downward communicative services, so as to use the limited number of the optical wavelengths efficiently.

In operation, the downward signals (transmitted from the base station 100 to the subscriber side 320) are used for both distribution services (e.g. CATV (Cable TV)) and communication services (e.g. B-ISDN (Broadband-Integrated Services Digital Network)), whereas the upward signals (transmitted from the subscriber side 320 to the central office 100) are used for the communication services only. The downward distributive service branches (divides) the downward signals into N signals using a single wavelength λ_0 and transmits the branched signals through N optical transmission lines. The downward communicative service (B-ISDN) allocates N unique wavelengths, one to each respective subscriber device, and the upward communicative service (B-ISDN) also allocates N unique

wavelength, one to each respective subscriber device. Therefore, it is necessary to secure (2N+1) wavelengths in order to accommodate N subscribers.

Specifically, the downward distribution service transmits the downward signal for a subscriber device S1 through an optical fibre 331 using the single wavelength λ_0 and the downward communication service transmits the downward signal for subscriber S1 through an optical fibre 332 using a corresponding wavelength λ_1. The wavelength λ_1 output from a WDM multiplexer/demultiplexer 312 associated with subscriber S1 is combined with the wavelength λ_0 received through the optical fibre 331 in a WDM multiplexer/demultiplexer 311, and the combined wavelength $\lambda_0\lambda_1$ is transmitted to the subscriber device S1 through an optical fibre 341. The combined wavelength is demultiplexed into the wavelengths λ_0 and λ_1 by a WDM multiplexer/demultiplexer 321 in the subscriber device S1. Subsequently, the wavelength λ_0 is converted to an electric signal in an optoelectric converter 322 and transmitted to a TV set, and the wavelength λ_1 is converted to an electric signal in an optoelectric converter 323 and transmitted to a B-ISDN terminal.

On the other hand, in the upward communication service, an optoelectric converter 324 converts the electric signal from the B-ISDN terminal to an optical signal 353, and the WDM multiplexer/ demultiplexer 321 upward transmits the converted optical signal through the optical fibre 341 at a wavelength λ_{N+1}, specific to subscriber S1. The signal on the optical fibre 341 is

transmitted to an optical fibre 334 through the WDM multiplexer/ demultiplexer 311 and then, transmitted to the central office through the WDM multiplexer/ demultiplexer 312 on an optical fibre 333. In the same manner, the other subscriber devices S2-SN in the subscriber side 320 use two unique wavelengths for communication services, and the single wavelength λ_0 for distribution services.

Since the conventional optical fibre subscriber networks mentioned above employ high density wavelength division multiplexing which uses more than three wavelengths, it is necessary to use wavelength variable filters or WDM multiplexers/ demultiplexers which require precise manufacturing technology. Therefore, in building many subscriber networks, there arises a safety problem and a cost problem. In particular, there is a limitation in expanding the new subscribers or increasing the communication speed.

Summary of the Invention

The invention preferably provides a method of wavelength division multiplex communication of a number of signals wherein a number (N) of common wavelengths are used in the multiplexing, information destined for a plurality of subscribers is transmitted on each common wavelength; each subscriber receives one or more of a selected sub-set (Q) of the number (N) of common wavelengths used in the multiplexing; and appropriate bandwidth of the common

wavelength is allocated to each subscriber communicating on that wavelength.

Preferably, the subset of common wavelengths of each subscriber is allocated by providing each subscriber device with a corresponding plurality (Q) of fixed wavelength filters, each corresponding to one common wavelength of the wavelengths used in the multiplexing.

Preferably, the bandwidth is allocated to each subscriber on receipt of a service request.

Preferably, the selected subset for each subscriber is different from selected subsets for other subscribers.

Preferably, the selected subset for each subscriber is unique to that subscriber.

Preferably, the method further comprises the steps of:

- transmitting a service request signal from a subscriber to an exchange;
- in the exchange, examining one wavelength of the sub-set of wavelengths corresponding to the subscriber, to determine the available bandwidth; and
- if the available bandwidth in the examined wavelength is sufficient to accommodate the requested service, allocating, in the exchange, a corresponding bandwidth in that wavelength, to the subscriber for the provision of the requested service.

Such a method preferably further comprises the steps of:

- if the available bandwidth in the examined wavelength is insufficient to accommodate the requested service,
- in the exchange, examining a further wavelength of the sub-set of wavelengths corresponding to the subscriber, to determine the available bandwidth; and
- if the available bandwidth in the further examined wavelength is sufficient to accommodate the requested service, allocating, in the exchange, a corresponding bandwidth in that wavelength, to the subscriber for the provision of the requested service.

In such a method, if none of the wavelengths of the subset of wavelengths contains sufficient bandwidth to accommodate the requested service, a high-speed wavelength may be allocated to the requesting subscriber.

Alternatively, if none of the subset of wavelengths has sufficient bandwidth, services already being provided on the subset of wavelengths may be re-arranged to collect sufficient available bandwidth onto one or more of the subset of wavelengths, and the collected available bandwidth may be allocated to the subscriber, for provision of the service.

In an embodiment of the invention, if none of the wavelengths of the subset of wavelengths contains sufficient bandwidth to accommodate the requested service, the requested service is not provided.

Preferably, the wavelengths are optical wavelengths, and the communication takes place over an optical fibre subscriber network.

The present invention also provides a subscriber device arranged so as to receive one or more of a specific subset of wavelengths, each of the specific wavelengths of the subset for the subscriber device remaining fixed, and being chosen from a total number (N) of wavelengths and each subscriber device being arranged to communicate over any one or more of the subset of wavelengths.

Preferably, the subset of wavelengths are chosen for each subscriber device such that different subscriber devices have a different combination of wavelengths in their respective subset, wherein more than one subscriber device is arranged to receive a certain common wavelength.

Preferably, the subscriber device is arranged to receive the subset of common wavelengths by providing a corresponding plurality (Q) of fixed wavelength filters, each corresponding to one common wavelength of the wavelengths used in the multiplexing.

The present invention preferably also provides a communications network comprising a plurality of optical subscriber devices as described, wherein each optical subscriber device is arranged to transmit service requests to a controller, and is further arranged to communicate over any one or more of the subset of

wavelengths, upon notification of allocation of corresponding bandwidth on the one or more wavelength(s).

In such a communications network, the subset for each subscriber device is preferably different from subsets for other subscriber devices. Each subscriber device is more preferably arranged so as to receive a unique subset of wavelengths.

The maximum number (Q) of wavelengths in each subset is preferably one half the total number (N) of wavelengths available in the system, to the nearest integer.

A communications network according to the present invention preferably further comprises a central office arranged to: transmit and receive information over a number (N) of wavelengths; receive service requests from individual subscriber devices; determine which of the wavelengths are comprised within the subset of wavelengths for that subscriber; assign bandwidth required for the requested service on one or more of the subset of wavelengths for that subscriber; inform the subscriber device accordingly; and to provide the requested service on the allocated bandwidth.

Preferably, the communications network is arranged such that, if none of the subset of wavelengths has sufficient bandwidth, services already being provided on the subset of wavelengths are re-arranged to collect sufficient available bandwidth onto one or more of the subset of wavelengths, and allocating the collected available

bandwidth to the subscriber, for provision of the service.

Alternatively, the communications network may be arranged such that, if none of the wavelengths of the subset of wavelengths contains sufficient bandwidth to accommodate the requested service, the requested service is not provided.

The wavelengths are preferably optical wavelengths, and the communication preferably takes place over an optical fibre subscriber network.

Accordingly, the invention provides an optical fibre subscriber network including a central office for allocating a unique combination of optical wavelengths to a subscriber upon receipt of a service request signal from the subscriber, WDM multiplexing service requested information together with the combined optical wavelength, and transmitting the WDM multiplexed optical wavelength through an optical fibre; and a plurality of optical subscriber devices for optically distributing, filtering and combining the WDM multiplexed optical signals received through the optical fibre to select optical wavelengths allocated thereto and outputting the selected optical wavelengths to corresponding subscriber terminals.

Preferably, the central office includes an exchange for allocating a combination of the wavelengths to a subscriber upon receipt of the service request signal

from the subscriber; a plurality of optical transmitters for converting electric signals output from the exchange to optical signals of unique wavelengths; a WDM multiplexer for multiplexing the optical signals output from the optical transmitters and transmitting the multiplexed optical signals to the optical fibre; and an optical amplifier for amplifying the output of the WDM multiplexer to compensate for transmission loss of the multiplexed optical signals being transmitted to the subscriber through the optical fibre.

Preferably, the optical subscriber device includes an optical distributor for distributing the WDM multiplexed optical signals received through an incoming optical fibre to Q internal optical fibres; a fixed optical filter for filtering a wavelength group allocated thereto out of the WDM multiplexed optical signals to receive an optical wavelength group pre-allocated in the central office; an optical receiver module connected to an output of the fixed optical filter, for converting the optical signals output from the fixed optical filter to electric signals; a concentrator for switching and concentrating an output of the optical receiver module to multimedia terminals connected to output ports of the optical subscriber device; and an electronic signal converter for converting an output of the concentrator so as to connect the multimedia terminals to the concentrator.

Further, the optical fibre subscriber network includes a plurality of optical distributors placed on the optical fibre intervening between the central office and the

optical subscriber devices, for distributing the optical signals output from the central office according to construction of a service requested network.

Further, the optical fibre subscriber device may include an optical amplifier placed on the optical fibre intervening between the central office and the optical subscriber devices, for compensating for distribution loss of the optical signals due to the optical distributors.

Information is preferably carried on each of the wavelengths by an ATM (asynchronous transfer mode) or packet switch protocol.

Preferably the present invention provides a WDM optical fibre subscriber network suitable for an expanded number of subscribers.

Brief Description of the Drawings

The present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

FIG. 1 is a block diagram of a first conventional WDM optical fibre subscriber network;

FIG. 2 is a block diagram of a second conventional WDM optical fibre subscriber network:

FIG. 3 is a block diagram of a third conventional WDM optical fibre subscriber network;

FIG.4 is a block diagram of a WDM optical fibre subscriber network according to an embodiment of the present invention;

FIG. 5 is a block diagram of an optical subscriber device (424) installed in the house of the subscriber according to an embodiment of the present intention; and

FIG. 6 is a flow chart illustrating a central office allocating services for the respective optical wavelength groups according to an embodiment of the present invention.

Detailed Prescription of the Drawings

In the accompanying drawings like reference numerals denote like elements.

FIG. 4 shows a block diagram of a WDM optical fibre subscriber network according to an embodiment of the present invention. Referring to FIG. 4, an optical fibre subscriber network consists of a central office 410, a subscriber side 420 including P subscribers S1-SP, and an upward/downward optical fibre cable 440. Cable 440 is an optical communication path for transmitting data between the central office 410 and the subscriber side 420. Here, the upward/downward optical fibre cable 440 has distributors 422 and 430 disposed at intervals upon it.

The central office 410 preferably includes an ATM (Asynchronous Transfer Mode) exchange 412 which is commonly used in wideband communication networks. In ATM communications, bandwidth is allocated dynamically, on demand, rather than being permanently allocated to a particular subscriber. N optical transmitters 414-1 to 414-N convert the electric signals output from the ATM exchange 412 to optical signals of unique wavelengths. A WDM multiplexer 416 multiplexes the optical signals output from the optical transmitters 414 and transmits these through the optical fibre cable 440. An optical amplifier 418 may be included for amplifying the output optical signals of the WDM multiplexer 416 to compensate for the loss of the optical signals. Such loss may be caused by the optical fibre cable 440 and/or the distributors 422 and 430 during transmission of the optical signals to the subscriber side 420.

Further, the subscriber side 420 includes P optical subscriber devices S1-SP, each arranged to respond to a number Q of wavelengths pre-allocated to that subscriber device. Information carried on the pre-allocated wavelengths may be transferred to a corresponding subscriber terminal. The detailed construction of the optical subscriber device for the first subscriber S1 is illustrated (424) in FIG. 5, by way of example.

FIG. 5 shows an optical subscriber device installable, for example, in the house of respective subscribers S1-SP according to an aspect of the present invention. An

optical distributor 502 distributes the WDM multiplexed optical signal received from the central office 410 via an incoming optical fibre 444-1 to Q optical fibres 512-1 to 512-Q.

A fixed optical filter 504 consists of Q different fixed optical filtering elements. Each of the fixed optical filtering elements filters a corresponding wavelength out of the N wavelengths WDM multiplexed in the multiplexed optical signal. Each filtering element passes a corresponding one of the N wavelengths onto an optic fibre 514-1 to 514-Q.

An optical receiver module 506 receives the signals from the fixed optical filter 504 over optic fibres 514-1 to 514-Q, and converts the received optical signals to electric signals. A concentrator 508 and an electronic signal converter 510 switch or concentrate the output of the optical receiver module 506 to multimedia terminals (e.g. a TV set, a telephone or facsimile, a video conference device, and a computer or work station) connected to output ports of the optical subscriber device 424. Electronic signal converter 510 converts an output of the concentrator 508 so that it is suitable for multimedia terminals.

In the presently described embodiment, an ATM exchange or a packet switching exchange protocol is used in the concentrator 508.

The electronic signal converter 510 uses a network connector for connecting the computer or the work station, a CODEC (Coder-DECoder) for connecting the TV set and the video conference device, or a PBX (Private Branch Exchange) for connecting the telephone or the facsimile.

In operation, the exchange 412 of the central office 410 constantly checks whether a connection request signal is received from a subscriber. To accommodate a requested service, a corresponding bandwidth of one of the wavelengths must be allocated. If a connection request signal from a subscriber is detected, the exchange 412 checks whether there is sufficient available bandwidth to allocate the corresponding subscriber, to provide the requested service. If the extra bandwidth is available, the exchange 412 notifies an internal service controller (known as a control layer) that it is possible to accommodate the requested service, and then updates a service allocation table.

When it is decided to accommodate the requested service through a particular wavelength, the exchange 412 enables optical transmission modules of the optical transmitters 414 to transmit the signals required for the requested service, on that particular wavelength.

The optical signals, each having different wavelengths, transmitted from the optical transmitters 414 are combined by the WDM multiplexer 416 and transmitted through the optical fibre cable 440. It is not necessary

that the respective transmission modules for the respective wavelengths should have the same information transmission rate.

To compensate for the distribution loss of the optical signals, the central office 410 may have an optical amplifier 418 at the final stage, if necessary.

The WDM multiplexed optical signals output from the central office 410 are transmitted through the optical cable 440 and are distributed by the optical distributors 430 and 422 according to the construction of the network. If necessary, the optical cable 440 may have further distributors, and the portion having the greater distribution loss may include a separate optical amplifier to compensate for the distribution loss.

The multiplexed optical signal, having reached a corresponding subscriber device 424 through the distributors 430 and 422, is distributed by a 1XQ optical distributor 502, and filtered by the fixed optical filter 504 consisting of Q optical filtering elements, each passing a specific wavelength. Each wavelength may be considered as functioning as an addresses of the physical layer (that is, equivalent to an address of an input port). The filtered Q optical wavelengths are transmitted through Q optical fibres 514-1 to 514-Q to the optical receiver module 506, which converts the received optical signals to electric signals. Allocation of bandwidth on a particular frequency directs the

optical receiver module 506 to use the corresponding filter 514-1 as the incoming data source.

Output signals of the optical receiver module 506 are transferred to the electronic signal converter 510 via the concentrator 508 which distributes, concentrates or switches the input signals suitable for the multimedia terminals.

FIG. 6 shows a flow chart illustrating allocation of bandwidth for requested services in the respective optical wavelength groups according to the present invention, as carried out in the central office 410 of the optical fibre subscriber network. Reference character "j" denotes an identification number of a subscriber wavelength group (corresponding to one of subscribers S1-SP) consisting of several (Q) different wavelengths. Reference character "i" denotes an identification number of an individual optical wavelength within each respective subscriber wavelength group.

Referring to FIG. 6, the exchange 412 (strictly speaking, a controller of the exchange 412) monitors the subscriber wavelength groups allocated to the subscribers S1-SP, from the first (j=1) to the last (j=P), at prescribed periods, to check whether a new service request signal is received (steps 602-608). At 602, j is set equal to 1. At 604, if no service request signal is detected, j is incremented at 606. At 608, if j is equal to, or greater than, P, the exchange returns to the start, at state 602.

If j is less than P, a service request signal is detected again at 604.

If a service request signal is present at 604, step 610 is performed. At step 610, i is set to 1. The exchange 412 determines the available remaining bandwidth of each optical wavelength of the subscriber group denoted by the value of j, from the first optical wavelength (i=1) towards the last optical wavelength (i=Q). It determines whether the detected remaining bandwidth on each wavelength is wider than or equal to the service requested bandwidth (steps 610-616), until a wavelength with sufficient remaining bandwidth is identified.

Specifically, the exchange 412 first determines the available bandwidth of the first optical wavelength (i=1), in steps 610 and 612. It then determines whether the determined available bandwidth is wider than or equal to the requested service bandwidth.

When the available bandwidth for any one of the subscriber optical wavelengths is equal to or wider than the requested service bandwidth, the exchange 412 allocates the requested bandwidth to provide the requested service to the requesting subscriber. The exchange notifies the upper service control layer that it is possible to accommodate the requested service and updates a service allocation table of the optical wav lengths (steps 618-622), and then returns to the step 602.

If the available bandwidth is narrower than the requested service bandwidth, the exchange 412 performs the same operation is steps 616 and 612, for the next optical wavelength ($i=i+1$). These steps are repeated, if necessary right through to the last optical wavelength ($i=Q$). The available bandwidth is determined even for the last optical wavelength ($i=Q$) and if it is narrower than the service requested bandwidth, the exchange 412 notifies the upper service control layer that it is impossible to accommodate the requested service (at step 624) and then returns to the step 602, to re-commence the process.

In conclusion, when N optical wavelengths are WDM multiplexed by the WDM multiplexer, the passive optical fibre subscriber network of the invention has a downward structure capable of providing connection service to P subscribers (where $P>N$). That is, N WDM multiplexed wavelengths are transmitted to each subscriber through the multistage optical distributors 430 and 422. Then, in each subscriber device, the fixed optical filter 504 passes a certain, preferably unique, combination of Q subscriber wavelengths (where $1<Q\leq N$) allocated to that subscriber. Accordingly, it is possible to increase the number of the connectable subscribers by allocating a combination of multiple subscriber wavelengths chosen from the N multiplexed wavelengths, rather than allocating one or more specific wavelength to each subscriber. Here, the number of the connectable subscribers which may each have a unique combination of subscriber wavelengths is determined by

$$P = C_N^Q = \frac{N!}{Q!(N-Q)!} \rangle\rangle N \ldots (1)$$

where P is the number of subscribers that may be connected and each have a unique combination of subscriber wavelengths, N is the total number of the optical wavelengths used by the system, and Q is the number of wavelengths allocated to each subscriber. It is found that P has a maximum value when Q=N/2 (where N is even), or Q=(N +/- 1)/2 (where N is odd).

For example, when N=16 and Q=4, the optical fibre subscriber network can accommodate P=1820 subscribers. In order to increase the number of the subscribers that can be allocated a unique combination of subscriber wavelengths, P may be increased by choosing an appropriate value of Q. Here, it is necessary to increase the number Q of subscriber wavelengths allocated to each subscriber. When 8 wavelengths are allocated to each subscriber (Q=8), the number P of connectable subscribers becomes 12870, i.e. 16!/(8!.8!). Further, use of the optical fibre subscriber network of the present invention can reduce use of the high-priced devices necessary in conventional optical fibre subscriber networks, such as the wavelength variable optical filter, the multiplexer/demultiplexer and the wavelength converter.

Further, when an existing subscriber requires high bandwidth services on the subscriber wavelengths, it is possible to reallocate the bandwidths on the subscriber wavelengths so as to allow the subscriber to use a

wavelength with a higher transmission rate or to additionally allocate bandwidth or a further wavelength, in addition to the existing subscriber wavelengths.

As described above, the optical fibre subscriber network of the invention is capable of supporting an increased number of connectable subscribers and reduces use of the wavelength variable optical filter or the WDM multiplexer which requires precise manufacturing technology, thereby contributing to the reduction in the cost of building optical fibre subscriber networks. In addition, when a certain subscriber requires an increase in communication capacity or speed, it is possible to easily enhance the quality of the services by additionally allocating extra bandwidth within a subscriber wavelength, or allocating a high-speed wavelength to that subscriber.

CLAIMS:

1. A method of wavelength division multiplex communication of a number of signals wherein:

- a number (N) of common wavelengths are used in the multiplexing,
- information destined for a plurality of subscribers is transmitted on each common wavelength;
- each subscriber receives one or more of a selected sub-set (Q) of the number (N) of common wavelengths used in the multiplexing; and
- appropriate bandwidth of the common wavelength is allocated to each subscriber communicating on that wavelength.

2. A method according to claim 1 wherein the subset of common wavelengths of each subscriber is allocated by providing each subscriber device with a corresponding plurality (Q) of fixed wavelength filters, each corresponding to one common wavelength of the wavelengths used in the multiplexing.

3. A method according to any preceding claim wherein the bandwidth is allocated to each subscriber on receipt of a service request.

4. A method according to any preceding claim wherein the selected sub-set for each subscriber is different from selected subsets for other subscribers.

5. A method according to any preceding claim wherein the selected subset for each subscriber is unique to that subscriber.

6. A method according to any preceding claim further comprising the steps of :

- transmitting a service request signal from a subscriber to an exchange;

- in the exchange, examining one wavelength of the sub-set of wavelengths corresponding to the subscriber, to determine the available bandwidth; and

- if the available bandwidth in the examined wavelength is sufficient to accommodate the requested service, allocating, in the exchange, a corresponding bandwidth in that wavelength, to the subscriber for the provision of the requested service.

7. A method according to claim 6 further comprising the steps of:

- if the available bandwidth in the examined wavelength is insufficient to accommodate the requested service,

- in the exchange, examining a further wavelength of the sub-set of wavelengths corresponding to the subscriber, to determine the available bandwidth; and

- if the available bandwidth in the further examined wavelength is sufficient to accommodate the requested service, allocating, in the exchange, a corresponding bandwidth in that wavelength, to the subscriber for the provision of the requested service.

8. A method according to claim 7 wherein, if none of the wavelengths of the subset of wavelengths contains sufficient bandwidth to accommodate the requested service, a high-speed wavelength is allocated to the requesting subscriber.

9. A method according to claim 7 wherein, if none of the subset of wavelengths has sufficient bandwidth, the services already being provided on the subset of wavelengths are re-arranged to collect sufficient available bandwidth onto one or more of the subset of wavelengths, and allocating the collected available bandwidth to the subscriber, for provision of the service.

10. A method according to claim 7 wherein, if none of the wavelengths of the subset of wavelengths contains sufficient bandwidth to accommodate the requested service, the requested service is not provided.

11. A method of communication according to any preceding claim wherein the wavelengths are optical wavelengths, and the communication takes place over an optical fibre subscriber network.

12. A method according to any preceding claim wherein information is carried on each of the wavelengths by an ATM (asynchronous transfer mode) or packet switch protocol.

13. A subscriber device arranged so as to receive one or more of a specific subset of wavelengths, each of the wavelengths of the subset for the subscriber device remaining fixed, and being chosen from a total number (N) of wavelengths and each subscriber device being arranged to communicate over any one or more of the subset of wavelengths.

14. A subscriber device according to claim 13 wherein the subset of wavelengths are chosen for each subscriber device such that different subscriber devices have a different combination of wavelengths in their respective subset, wherein more than one subscriber device is arranged to receive a certain common wavelength.

15. A subscriber device according to claim 13 or 14 which is arranged to receive the subset of common wavelengths by providing a corresponding plurality (Q) of fixed wavelength filters, each corresponding to one of the common wavelengths used in the multiplexing.

16. A communications network comprising a plurality of optical subscriber devices according to any of claims 13-15, wherein each optical subscriber device is arranged to transmit service requests to a controller, and is further arranged to communicate over any one or more of the subset of wavelengths, upon notification of allocation of corresponding bandwidth on the one or more wavelength(s).

17. A communications network according to claim 16 wherein the subset for each subscriber device is different from subsets for other subscriber devices.

18. A communications network according to claim 17 wherein each subscriber device is arranged so as to receive a unique subset of wavelengths.

19. A communications network according to any of claims 16-18 wherein the maximum number (Q) of wavelengths in each subset is one half the total number (N) of wavelengths available in the system, to the nearest integer.

20. A communications network according to any of claims 16-19 further comprising a central office arranged to :

- transmit and receive information over a number (N) of wavelengths;
- receive service requests from individual subscriber devices;
- determine which of the wavelengths are comprised within the subset of wavelengths for that subscriber;
- assign bandwidth required for the requested service on one or more of the subset of wavelengths for that subscriber;
- inform the subscriber device accordingly; and to
- provide the requested service on the allocated bandwidth.

21. A communications network according to any of claims 16-20 arranged such that, if none of the subset of

wavelengths has sufficient bandwidth, services already being provided on the subset of wavelengths are re-arranged to collect sufficient available bandwidth onto one or more of the subset of wavelengths, and allocating the collected available bandwidth to the subscriber, for provision of the service.

22. A communications network according to any of claims 16-20 arranged such that, if none of the wavelengths of the subset of wavelengths contains sufficient bandwidth to accommodate the requested service, the requested service is not provided.

23. A communications network according to any of claims 16-22 wherein the wavelengths are optical wavelengths, and the communication takes place over an optical fibre subscriber network.

24. An optical fibre subscriber network comprising:

- a central office for allocating a unique combination of optical wavelengths to a subscriber upon receipt of a service request signal from said subscriber, WDM (Wavelength Division Multiplexing) multiplexing service requested information together with said combined optical wavelength, and transmitting the WDM multiplexed optical wavelength through an optical fibre; and

- a plurality of optical subscriber devices for optically distributing, filtering and combining said WDM multiplexed optical signals received through the optical fibre to select optical wavelengths allocated thereto and

outputting the selected optical wavelengths to corresponding subscriber terminals.

25. The optical fibre subscriber network as claimed in claim 24, wherein said central office comprises:

- an exchange for allocating a combination of the wavelengths to a subscriber upon receipt of the service request signal from said subscriber;

- a plurality of optical transmitters for converting electric signals output from said exchange to optical signals of unique wavelengths;

- a WDM multiplexer for multiplexing the optical signals output from said optical transmitters and transmitting the multiplexed optical signals to the optical fibre; and

- an optical amplifier for amplifying the output of the said WDM multiplexer to compensate for transmission loss of the multiplexed optical signals being transmitted to the subscriber through the optical fibre.

26. The optical fibre subscriber network as claimed in claim 24 or claim 25, further comprising a plurality of optical distributors placed on said optical fibre intervening between said central office and said optical subscriber devices, for distributing the optical signals output from said central office according to construction of a service requested network.

27. The optical fibre subscriber device as claimed in any of claims 24-26, further comprising an optical amplifier placed on said optical fibre intervening

between said central office and said optical subscriber devices, for compensating for distribution loss of the optical signals due to said optical distributors.

28. An optical fibre subscriber device comprising:

- an optical distributor for distributing the WDM multiplexed optical signals received through an incoming optical fibre to Q internal optical fibres;

- a fixed optical fibre for filtering a wavelength group allocated thereto out of the WDM multiplexed optical signals to receive an optical wavelength group pre-allocated in said central office;

- an optical receiver module connected to an output of said fixed optical filter, for converting the optic signals output from said fixed optical filter to electric signals;

- a concentrator for switching and concentrating an output of said optical receiver module to multimedia terminals connected to output ports of said optical subscriber device; and

- an electronic signal converter for converting an output of said concentrator so as to connect the multimedia terminals to said concentrator.

29. A network or a subscriber device according to any of claims 13-28 wherein the wavelengths are optical wavelengths, and the communication takes place over an optical fibre subscriber network.

30. A network or a subscriber device according to any of claims 13-29 wherein information is carried on each of

the wavelengths by an ATM (asynchronous transfer mode) or packet switch protocol.

31. A communications system substantially as described and/or as illustrated in Figs. 4-6 of the accompanying drawings.

32. A subscriber device substantially as described and/or as illustrated in Figs. 4-6 of the accompanying drawings.

33. A method of wavelength division multiplex communication substantially as described and/or as illustrated in Figs. 4-6 of the accompanying drawings.